Chapter 2
Evolution of the Nuclear Deterrent – A History

2.1 Overview

An understanding of the unique status of nuclear weapons is integral to understanding their role. An early realization of their unrivaled destructive power necessitated the development of separate and unique systems and procedures to produce, field, maintain, deploy, employ, and dispose of these special weapons. From the dawn of the nuclear era, even a new vocabulary was required to discuss atomic warfare. Among these terms was the ominous phrase “mutual assured destruction” (MAD), with its connotations of Armageddon and the culture of impending doom it created.

2.2 Nuclear Weapons from 1939–1945

The potential to release nuclear energy for military use was first described in a letter signed by Dr. Albert Einstein to President Franklin D. Roosevelt in August 1939. The letter, written by Einstein at the urging of Dr. Leó Szilárd, described the possibility of setting up a nuclear chain reaction in a large mass of uranium, a phenomenon that would lead to the construction of bombs, and concluded with the statement that experimental

Albert Einstein
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August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

-2-

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;

b) to speed up the experimental work,which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,
A. Einstein
(Albert Einstein)

work grounded in these principles was being carried out by the Nazis in Berlin. Einstein's statement that "such bombs might very well prove to be too heavy for transportation by air" did not diminish his estimate of the potential for a huge increase in the destructive capacity of a single bomb, which he thought could be carried or delivered to a target by ship.

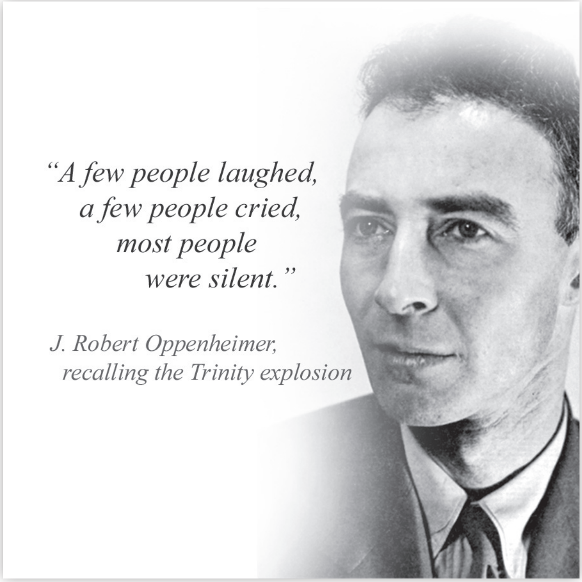
In early 1940, two physicists, Austrian Otto Frisch and German Rudolph Peierls, both of whom had sought refuge from the Nazis and were working at Birmingham University in England, wrote a memorandum suggesting that if a five kilogram mass of uranium-235 (U-235) were made fissionable, it would release an atomic explosion equivalent to thousands of tons of dynamite. Frisch and Peierls explained a method of separating the U-235 and detonating it in a bomb, discussed the radiological hazards the explosion would create, and examined the moral implications of the bomb's use. The significance of Frisch's and Peierls' breakthrough, a massively powerful bomb, light enough to be carried by an aircraft, soon resonated through the government of the United Kingdom, and, in the summer of 1941, the UK government-appointed Maud Committee presented its report endorsing Frisch's and Peierls' conclusions. The Maud Committee report described the facility and processes needed to build an atomic bomb and provided an estimate of the cost. Shortly thereafter, Prime Minister Winston Churchill authorized work to begin on Britain's atomic bomb project, managed by the Nuclear Weapon Directorate, code named *Tube Alloys.*[1]

The first Maud Committee report was sent from Britain to the United States in March 1941, but no comment was received in return. Given the lack of response, a member of the committee flew secretly to the United States in August 1941 to discuss the findings. Subsequent to these discussions, the National Academy of Sciences proposed an all-out U.S. effort to build nuclear weapons.

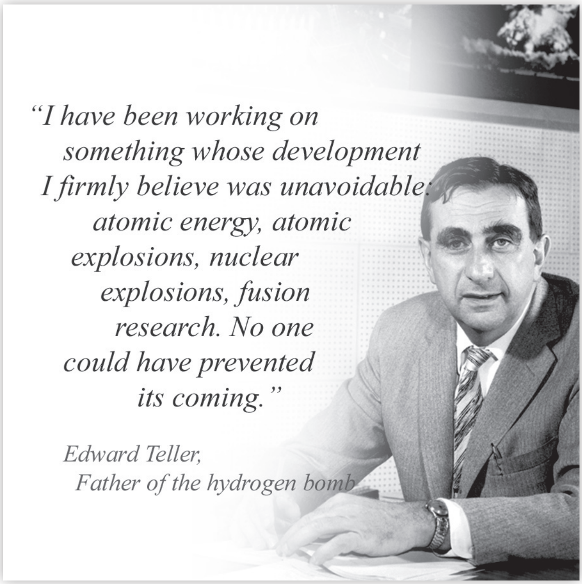
In a meeting on October 9, 1941, President Roosevelt was impressed with the need for an accelerated program, and by November had authorized the "all-out" effort recommended by the Academy and encouraged by the British. A new U.S. policy committee, the Top Policy Group, was created to inform the President of developments in the program. The first meeting of the group took place on December 6, 1941, one day before the Japanese

[1] Eventually, the term "tube alloy" was used as the code word for plutonium, whose existence was kept secret at that time. A few years later, scientists in the United States used the term "tuballoy" to refer to depleted uranium.

Prime Minister Mackenzie King, President Franklin D. Roosevelt, and Prime Minister Winston Churchill, Quebec Agreement, August 18, 1943 attack on Pearl Harbor and the entry of the United States into World War II.



Eventually, these efforts led the United States to establish the Manhattan Engineering District, also known as the "Manhattan Project," whose goal was to develop and produce nuclear bombs in time to affect the outcome of World War II. In 1943, as outlined in the Quebec Agreement, the team of scientists working on the British project was transferred to the Manhattan Project along with several scientists from Canada. The U.S. Army Corps of Engineers and Major General Leslie Groves provided oversight management and control of the Manhattan Project, which eventually employed more than 130,000 people. Dr. J. Robert Oppenheimer served as the civilian director of the scientific and engineering research and development activities.



On July 16, 1945, the United States detonated the first nuclear explosive device called "Gadget" at the Trinity Site, located within the current White Sands Missile Range, near the town of Alamogordo, New Mexico. Just 21 days later, on August 6, President Harry S. Truman authorized a specially equipped B-29 bomber named *Enola Gay* (**Figure 2.1**) to drop a nuclear bomb, *Little Boy* (**Figure 2.2**), on Hiroshima, Japan. Soon after Hiroshima was attacked, President Truman called for

Figure 2.1 Enola Gay

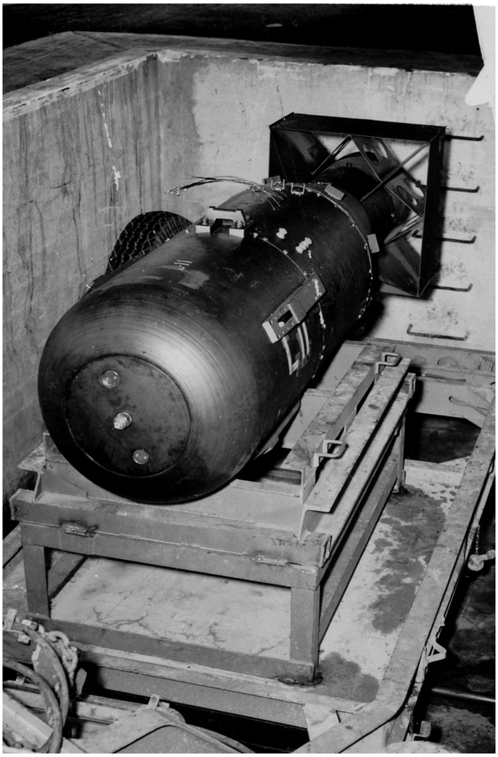


Figure 2.2 Little Boy

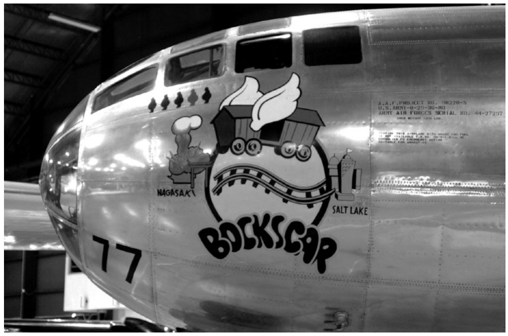


Figure 2.3 Bockscar

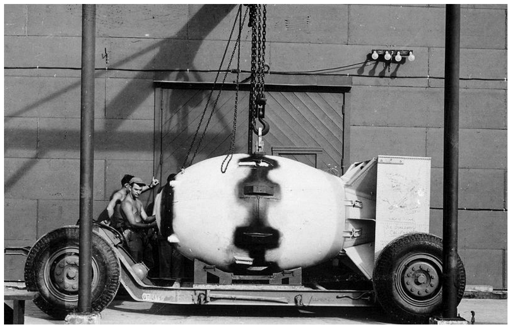


Figure 2.4 Fat Man

Japan's surrender. With no response from the Japanese after three days, on August 9, another B-29 bomber, *Bockscar* (**Figure 2.3**), dropped a second U.S. atomic weapon, *Fat Man* (**Figure 2.4**), on Nagasaki.

On August 14, 1945, Japan surrendered. The use of nuclear weapons had shortened the war and reduced the number of potential casualties on both sides by precluding a planned U.S. land invasion of Japan. The atomic bombs dropped on Hiroshima and Nagasaki remain the only nuclear weapons ever used in warfare. Many have said their use permanently altered the global balance of power.

2.3 Nuclear Weapons from 1945–1992

The United States enjoyed a nuclear monopoly until the Soviet Union conducted its first nuclear test on August 29, 1949. On October 3, 1952, following the resumption of its independent nuclear weapons program in 1947, the United Kingdom detonated its first nuclear device, becoming the third nation to become nuclear weapons-capable. Less than a month later, on November 1, 1952, the United States detonated its first thermonuclear[2] device, followed nine months later by the Soviet Union's first thermonuclear test. The arms race was on.

Both the United States and the Soviet Union increased their stockpile quantities until each possessed nuclear weapons in sufficient quantities to achieve a second-strike capability, meaning both sides would be capable of massive retaliation even after absorbing an all-out first strike. In this way, the United States and the Soviet Union were certain of mutual assured destruction, which provided both nations deterrence against hostilities toward one another. These were the uneasy years of the nuclear "balance of terror," when the potential for total devastation from a superpower nuclear exchange was the most urgent threat facing the Nation and the prospect of an attack against the North Atlantic Treaty Organization (NATO) in Western Europe was on the forefront in U.S. military planning.

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For the first decade or so of the nuclear era, the U.S. nuclear weapons program was focused on producing sufficient nuclear material to build enough weapons to support a nuclear capability for almost every type of military delivery system available at the time. This was considered essential because of the possibility of Cold War escalation, specifically, the danger that a potential U.S.-Soviet conflict would escalate from a conventional confrontation to the limited use of battlefield and tactical nuclear weapons to an all-out strategic nuclear exchange. Throughout the late 1950s, the United States was committed to increasing nuclear weapons quantities to enhance

[2] A thermonuclear weapon uses both nuclear fission and nuclear fusion to produce a greatly increased yield in a device small enough to be delivered as a weapon.


TRINITY SITE
WHERE
THE WORLD'S FIRST
NUCLEAR DEVICE
WAS EXPLODED ON
JULY 16, 1945

flexibility in the types of nuclear-capable military delivery vehicles and the bombs and warheads available for delivery.

By the end of 1967, both the Soviet Union and the United States each had more than 30,000 nuclear weapons. Most of these warheads had relatively low yields and were for short-range, non-strategic (also called “tactical” or “theater”) systems.[3] At the time, many U.S. weapons were in Europe within the territories of NATO allies. For the United States, the large number of stockpiled non-strategic weapons offset the vast advantage the Soviet Union had in conventional military forces. Beginning in 1968, the United States shifted priorities and began a significant reduction in non-strategic nuclear weapons.

Then by 1991, when the United States signed the first Strategic Arms Reduction Treaty (START I), the total U.S. stockpile was approximately 19,000 nuclear weapons. Also in 1991, President George H. W. Bush initiated further reductions in non-strategic nuclear weapons. In the *Presidential Nuclear Initiative* (PNI) of 1991, the President announced the United States would retain only a small fraction of the Cold War levels of non-strategic nuclear weapons. The PNI decision significantly reduced the number of U.S. forward-deployed nuclear weapons in Europe and eliminated all non-strategic systems, with the exception of gravity bombs, retained primarily to support NATO in Europe, and the Tomahawk sea-launched cruise missile (SLCM), which was removed from deployment but not immediately retired.

Furthermore in the mid-1960s, the United States shifted priorities from quantity to sophistication and U.S. nuclear stockpile production established a recurring pattern of deployment, fielding, and then replacement by more modern weapons. Thus, from the mid-1960s until 1992, the U.S. nuclear weapons program was characterized by a continuous cycle of modernization programs. In addition to warheads that were simpler[4] for the military operator, modern characteristics included greater yield, smaller size,[5]

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3 Non-strategic or tactical nuclear weapons refer to nuclear weapons designed to be used on a battlefield in military situations. This is opposed to strategic nuclear weapons, which are designed to be used against enemy cities, factories, and other larger-area targets to damage the enemy’s ability to wage war.

4 As a function of simplicity, the United States moved away from warheads requiring in-flight insertion (IFI) of the nuclear component, to warheads that were self-contained sealed-pit devices (“wooden rounds”) without requiring the military operator to insert components, or “build” the warhead. While these warheads may have been more complex internally, this was transparent to the operator and the pre-fire procedures were much simpler.

5 Smaller warhead size allowed strategic missiles to carry a larger number of reentry bodies/vehicles and made nuclear capability possible for a greater number of delivery methods, including the possibility for nuclear weapons to be human-portable or fired by cannon artillery.

better employment characteristics,[6] and more modern safety, security, and control features. A key part of this process was the use of nuclear testing for a wide variety of purposes,[7] including the ability to:

- better understand nuclear physics and weapon design and functioning;
- determine more accurately the nature and distances associated with nuclear detonation effects;
- refine new designs in the development process;
- test the yield of weapons;
- confirm or define certain types of safety or yield problems found in nuclear components in weapons already fielded; and
- certify the design modification required to correct those problems.

During this time the United States utilized a complementary combination of underground nuclear testing and non-nuclear testing and evaluation to refine designs in the development stage, certify weapon designs and production processes, validate safety, estimate reliability, detect defects, and confirm effective repairs. In order for a nuclear weapon to be fielded, it had to go through development, testing and evaluation, initial and subsequent full-scale production, and, finally, fielding for possible wartime employment. Eventually, as the weapon aged and additional modern safety, security, and operational design features became available, the United States began development of a newer, better, and more sophisticated system to replace the fielded weapon. These modernization programs were usually timed to provide replacement weapons after the older warheads had been deployed for 15 to 20 years, a period known as the "protected period."

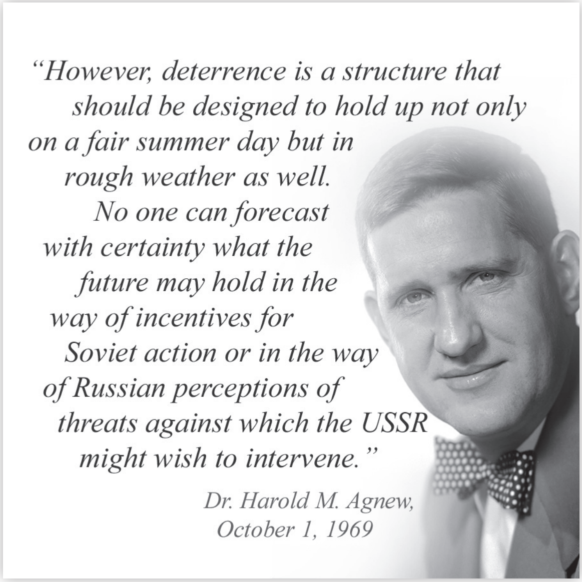
2.4 End of Underground Nuclear Testing

Throughout the 20th century, most nations that developed nuclear weapons tested them to obtain information about how the weapons worked, as well as how the weapons behaved under various conditions and how personnel, structures, and equipment behaved when

[6] Some of the features that provided increased operational capability included selectable yields, better fuzing (for a more accurate height of burst), increased range (for cannon-fired warheads), and shorter response times.

[7] The United States conducted nuclear tests from 1945 until 1992. The United States, together with the United Kingdom, the Soviet Union, and France, observed a voluntary moratorium on testing from October 1958 to 1960. The moratorium was broken by France in 1960, and the United States and the Soviet Union resumed testing in 1961.

subjected to nuclear explosions. In 1963, three (United States, United Kingdom, Soviet Union) of the four nuclear states and many non-nuclear states signed the *Limited Test Ban Treaty,* pledging to refrain from testing nuclear weapons in the atmosphere, underwater, or in outer space. The Treaty, however, permitted underground nuclear testing. France continued atmospheric testing until 1974 and China continued until 1980. Then in 1992 the United States voluntarily suspended its program of nuclear testing. Public Law (Pub. L.) 102-377, the legislation that halted U.S. nuclear testing, had several key elements. The law included a provision for 15 additional nuclear tests to be conducted by the end of September 1996 for the primary purpose of modifying weapons in the established stockpile to include three modern safety features.[8] However, with a limit of 15 tests within less than four years and without any real advance notice of the requirement, there was no technically credible way, at the time, to certify design modifications that would incorporate any of the desired safety features into existing warhead-types.[9] Therefore, the decision was made to forgo the 15 additional tests permitted under the new law and no other tests were conducted.[10]



This nuclear test prohibition impacted the stockpile management process in several significant ways. First, the legislation was too restrictive to achieve the objective of

[8] Pub. L. 102-377, the *Fiscal Year 1993 Energy and Water Development Appropriations Act*, specified three desired safety features for all U.S. nuclear weapons: enhanced nuclear detonation safety (ENDS), insensitive high explosive (IHE), and a fire-resistant pit (FRP).

[9] At the time the legislation was passed in 1992, scientists estimated that each modification to any given type of warhead would require at least five successful nuclear tests, which had to be done sequentially; one test was necessary to confirm that the modification did not corrupt the wartime yield, and four tests were needed to confirm nuclear detonation safety for four different peacetime abnormal environments.

[10] The 1992 legislation also stated that if, after September 30, 1996, any other nation conducted a nuclear test, then the restriction would be eliminated. Since October 1996, several nations have conducted nuclear tests. The current restriction is one of policy, not of law.

improving the safety of those already-fielded warhead-types. Second, the moratorium on underground nuclear testing also resulted in suspending production of weapons being developed with new, untested designs. These changes resulted in a shift toward a second paradigm for the U.S. nuclear weapons program. The modernization and production cycle, in which newer-design warheads replaced older warheads, was replaced by a new strategy of indefinitely retaining existing warheads without nuclear testing and with no plans for weapon replacement. Third, the underground nuclear testing moratorium created an immediate concern for many senior stockpile managers that any weapon-type that developed a nuclear component problem might have to be retired because nuclear tests could no longer be used to define the specific problem and confirm the correcting modification was acceptable. Without nuclear testing, there was a possibility that one weapon-type after another would be retired because of an inability to correct emerging problems, which might eventually lead to unintended, unilateral disarmament by the United States. While this has not occurred, it was a projected issue in 1992.

2.5 Nuclear Stockpile Since 1992

In response to these new circumstances and the resulting paradigm shift, the *National Defense Authorization Act for Fiscal Year 1994* (Pub. L. 103-160) required the Department of Energy (DOE) to "establish a stewardship program to ensure the preservation of the core intellectual and technical competencies of the United States in nuclear weapons." In the absence of nuclear testing, the DOE Stockpile Stewardship Program was directed to support a focused, multifaceted program to increase the understanding of the enduring stockpile; predict, detect, and evaluate potential problems due to the aging of the stockpile; refurbish and remanufacture weapons and components, as required; and maintain the science and engineering institutions needed to support the Nation's nuclear deterrent, now and in the future. In other words, the nuclear weapons establishment was called upon to determine how to ensure the continued safety, security, and effectiveness of the weapons in the U.S. nuclear stockpile without underground testing and without any plan to replace aging weapons, even as they aged beyond any previously experienced lifespan.

Public Law 103-160 required the Department of Energy to "establish a stewardship program to ensure the preservation of the core intellectual and technical competencies of the United States in nuclear weapons."

This Stockpile Stewardship Program has served as a substitute for nuclear testing since 1992, maintained the stockpile, and includes advanced computer simulations, experiments, enhanced surveillance, and the data from more than 1,000 previous nuclear tests.

Since early 1993, the United States has maintained its nuclear stockpile through a newer, shortened process comparable to the previous cycle of development, production, retirement, and replacement. The process of *modernize* and *replace* became one of *retain* and *maintain*, consisting primarily of activities associated with the continuous assessment, maintenance and repair, and refurbishment of U.S. nuclear weapons. Periodic reductions in quantities corresponded with the U.S. reductions in strategic forces associated with strategic force reduction treaties.

With the entry into force of START I in 1994, the United States was on a path to a total stockpile of approximately 10,000 weapons, of which the majority were strategic weapons. As a result of the 2003 *Strategic Offensive Reductions Treaty* (SORT) and the 2004 *Strategic Capabilities Assessment*, the United States reduced its total nuclear weapons stockpile to approximately 5,113 weapons in 2009. New START has led to further reductions in the total number of U.S. nuclear weapons and by the end of September 2014, the U.S. nuclear stockpile consisted of 4,717 warheads. **Figure 2.5** shows the size of the U.S. nuclear stockpile from 1945 to 2014.

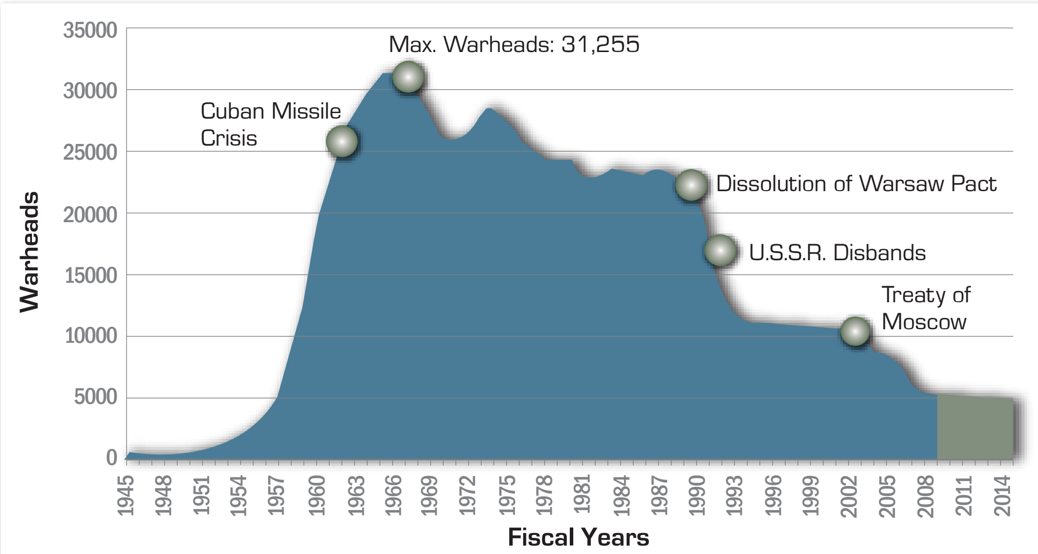


Figure 2.5 U.S. Nuclear Weapons Stockpile, 1945–2014
[Includes active and inactive warheads. Several thousand additional nuclear warheads are retired and awaiting dismantlement.]